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(54) Title: WIDEBAND RANGING PROCESS FOR FREQUENCY ACQUISITION

(57) Abstract: A system and method for synchronizing a hub radio (10) and a remote radio (15) to the same frequency in stepwise
fashion as a function of a predetermined frequency offset.

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# WIDEBAND RANGING PROCESS FOR FREQUENCY ACQUISITION

## BACKGROUND OF THE INVENTION

Applicant's disclosure is directed to an improved method of synchronizing a hub radio and a remote radio. Specifically, applicant's disclosure is directed to an improved method of synchronizing plural radios in a point-to-multipoint Broadband Wireless Access (BWA) communication system which uses Time Division Multiple Access (TDMA).

In a conventional communication system, each transceiver or radio may have a modem for modulating and demodulating the signals communicated between the transceivers. In order for a demodulator to correctly demodulate a received signal, the frequency of the receiving transceiver must be synchronized to the frequency of the transmitting transceiver. The process of synchronizing the frequency of one transceiver with the frequency of another transceiver is known as ranging. The ranging process typically occurs when a transceiver is first powered up, and then periodically to ensure it is synchronized with other transceivers in the system. Typically, the frequency of one of the transceivers is held constant while the frequency of the other transceivers is adjusted to synchronize the frequencies.

In a conventional point-to-multipoint communication system, in which a hub radio communicates with a

plurality of remote radios utilizing a single frequency, it is common to use Time Division Multiple Access (TDMA) to prevent interference between the radios. It is crucial that the hub and the remote radios are

5      synchronized to the same frequency. In principal, each of the radios transmit at the same frequency. However, due to frequency source uncertainties, which may vary from radio to radio, the signals transmitted to the hub radio may arrive with varying frequency offsets. If the

10     frequency offset for a given remote radio is greater than the frequency tolerance of the hub radio, the hub radio will be unable to synchronize with that remote radio. For a point-to-multipoint communication system, it is common to maintain the frequency of the hub radio

15     constant, and adjust the frequency of each of the remote radios to match the frequency of the hub radio.

In one prior art ranging process, the hub radio will transmit a synchronization signal to the remote radios. Each remote radio will then perform a complex

20     quantitative sampling of the received synchronizing signal and derive the frequency of the hub radio from the synchronizing signal. The remote radio will then adjust is frequency to match that of the hub radio. The remote will send a ranging signal at the newly adjusted

25     frequency and this iterative process between the remote radio and the hub radio continues until the radios are synchronized or some predetermined time limit is reached. This type of ranging process requires that

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each remote have the ability to perform complex signal processing in order to derive the frequency of the hub radio from the synchronizing symbol.

In another prior art ranging process, the remote
5   radio initiates the process by providing a ranging signal to the hub radio. The hub radio samples the received ranging signal and estimates the transmission frequency of the remote radio. The hub radio determines the frequency offset between the respective frequencies
10  of the hub radio and the remote radio and determines a frequency offset correction necessary to adjust the frequency of the remote radio to match the frequency of the hub radio. The hub radio transmits a synchronizing signal to the hub radio which provides the remote radio
15  with the frequency offset correction. The remote radio receives the frequency offset correction from the synchronizing signal and adjusts its frequency accordingly. The remote radio will transmit another ranging signal at the adjusted frequency and this
20  iterative process between the remote radio and the hub radio continues until the radios are synchronized or some predetermined time limit is reached. This type of ranging process requires that the hub radio have the capability to perform complex signaling processing and
25  waveform analysis of the ranging signals in order to determine the frequency offset for each of the remote radios.

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Thus, the prior art ranging systems typically require complex and expensive signaling processing equipment. These prior art ranging systems are generally unable to synchronize radios where the

5    frequency offset between the radios exceeds 64kHz. In Broadband Wireless Access (BWA) systems, it is not uncommon to see frequency offsets in excess of 64 kHz, and therefore the prior art synchronization systems are not adequate for use in a BWA communication systems.

10   The present disclosure is directed to a synchronizing method which does not require complex signaling processing and is able to synchronize at frequency offsets much greater than the prior art systems.

15   Accordingly, it is an object of the present invention to provide a novel method and of achieving synchronization between radios in a point-to-multipoint TDMA communication system.

It is another object of the present invention to

20   provide a novel method of increasing the frequency range of capture for a radio synchronization system.

It is yet another objective of the present invention to provide a novel system for frequency synchronization that does not require complex signaling processing.

25   It is still another object of the present invention to provide a novel method of frequency synchronization between a hub radio and remote radios in a BWA system.

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It is yet still another object of the present invention to provide a novel system for reducing the time required to synchronize radios.

It is still another object of the present invention to provide a novel method of synchronizing a remote radio with a hub radio as a function of the hub radio's frequency tolerance.

These and many other objects and advantages of the present invention will be readily apparent to one skilled in the art to which the invention pertains from a perusal of the claims, the appended drawings, and the following detailed description of the preferred embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial representation of a conventional TDMA communication system.

Figure 2 is a high level schematic representation of a conventional ranging process utilizing a cable modem.

Figure 3 is a high level graphical representation of the ranging process utilized by the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates a typical arrangement of a prior art point to multipoint communication system. The hub radio 10 transmits simultaneously to all remote radios 20 within the hub radio's transmission area using continuous transmission. The remote radios 20 transmit to the hub radio 20 using burst transmission. Because

each of the remotes transmit at the same frequency, Time
Division Multiple Access (TDMA) is used to prevent
interference between the radios.   While in theory, each
of    the    remotes    transmits    at    the    same    frequency,
5    frequency source tolerance, fading and doppler shifting
introduce frequency offsets.

Figure    2    illustrates    a    cable    modem    communication
system which uses a typical ranging technique to correct
the frequency offset between a hub radio and a remote
10   radio.   The hub radio and remote radio both include an
RF    transmit    and    receive    section,    a    modulator,    a
demodulator and a media access controller (MAC).

In operation, a process called ranging occurs when a
remote    is    first    turned    on,    and    then    at    periodic
15   intervals, to correct any frequency offset that may be
introduced    to    a    remote    from    frequency    source
uncertainties.   During ranging, a burst transmission is
sent  from the remote radio 15 to the hub radio 10.   The
hub RF section 20 receives the ranging transmission and
20   sends it to the demodulator 22.    The demodulator 22
estimates    the    frequency    of    the    received    burst    and
provides it to the MAC 23.   The demodulator can estimate
the frequency of the received signal using conventional
quantitative    signal    sampling    techniques.    The    MAC  23
25   receives the frequency estimation of the received signal
and determines a frequency offset correction for the
remote radio 15 necessary bring the remote radio in
synchronization with the hub radio 10.    The frequency

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offset correction from the MAC 23 is transmitted to the remote radio 15 via the modulator 21 and RF section 20.

The remote radio 15 receives the frequency offset correction information at the RF section 25 and passes 5 the information to the MAC 28 via the demodulator 26. The MAC 28 adjusts the transmitting frequency of the remote radio 15 to correct the frequency offset. This cycle of the remote transmitting a ranging signal and the hub providing frequency offset correction continues 10 until the hub radio is able to synchronize with the remote radio.

While the described prior ranging process is adequate to maintain the remote radios in synchronization with the hub radios for standard TDMA 15 systems such as cable modem systems where the frequency offset is typically less than 64kHz, it is unable to maintain the radios in synchronization at higher frequency offsets experienced in Broadband Wireless Access systems where frequency offsets can be as high as 20 400kHz.

Applicant's disclosure provides a communication system that permits radio synchronization at higher frequency offsets than permitted by the conventional system and yet does not require the complex quantitative 25 signal analysis used to estimate frequency offsets.

In one embodiment, a TDMA point-to-multipoint Broadband Wireless Access (BWA) communication system is capable of synchronizing with frequency offsets as high

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as 400kHz. Applicant's disclosure does not require a complex frequency estimation and does not try to determine the frequency offset between the remote radio and the hub radio. Rather, the frequency of the remote

5  radio is changed to a predetermined frequency offset, and then the frequency is stepwise changed as a function of the tolerance of the hub radio to synchronize.

Figure 3 illustrates the ranging process of applicant's disclosure. The hub radio operates at a

10  frequency $f_0$. The hub radio demodulator has a frequency tolerance of $\pm\Delta f_1$, such that the demodulator will be able to demodulate a signal if the received frequency is $f_0\pm\Delta f_1$. At time $t_1$, the remote radio transmits at an initial ranging signal at a first frequency $f_{remote}$. The

15  remote transmission is received at the demodulator and the demodulator attempts to synchronize with the signal for a predetermined period of time. The frequency of the ranging signal is outside of the hub demodulator's synchronization tolerance and therefore the demodulator

20  will be unable to demodulate the transmission. At the expiration of the predetermined time period, the hub radio will send an initial synchronizing message to the remote radio to change the frequency of transmission to an initial ranging frequency $-f_2$, which is a

25  predetermined offset $-\Delta f_2$ from $f_0$.

At time $t_2$, the remote radio changes its transmission frequency to $-f_2$ and transmits another ranging signal to the hub radio. The hub demodulator will again attempt

to synchronize with the ranging signal from the remote radio. After a predetermined period of time the hub demodulator will be unable to demodulate the ranging signal and the hub radio will send a synchronizing

5 message to the remote radio to increase its transmitting frequency by a predetermined frequency correction, $2\Delta f_1$. In a preferred embodiment, the predetermined frequency correction is a function of the frequency tolerance of the hub radio to synchronize with the remote radio.

10 Preferably, the predetermined frequency correction is approximately equal to the frequency tolerance of the hub radio to maximize the step increase in frequency of the remote radio while preventing the remote frequency from overshooting the frequency synchronization range of

15 the hub radio.

At time $t_3$, the remote increases its transmission frequency by $2\Delta f_1$ and transmits another ranging signal to the hub radio. The hub demodulator will again attempt to synchronize with the ranging signal from the remote

20 radio. Because the remote frequency is not within the frequency tolerance of the hub radio, the hub demodulator will be unable to demodulate the ranging signal and after a predetermined period of time the hub radio will send a synchronizing message to the remote

25 radio to again increase its transmitting frequency by the predetermined frequency correction, $2\Delta f_1$.

With continued reference to Figure 3, at time $t_4$, the remote frequency is increased by $2\Delta f_1$ and a ranging

signal is sent from the remote to the hub. The remote
frequency is now within the frequency tolerance of the
hub radio and therefore synchronization is achieved.
Once synchronization is achieved at time $t_5$, the hub
5    radio will fine tune the remote frequency to $f_0$ by
performing conventional quantitative analysis of the
received ranging signal and provide a fine tuning
synchronization signal to the remote radio. Note that
up until the time that the remote radio synchronizes
10   with hub radio at time $t_5$, no quantitative signal
sampling is required. Thus, applicant's process
achieves synchronization between a hub radio and a
remote radio without the use of complex signal sampling
processing common in the prior art.

15        This stepwise change in the remote frequency
continues until the hub radio can synchronize with the
remote radio, or a predetermined time limit, frequency
limit or some other limit is reached. In one embodiment
of applicant's disclosure, the remote frequency will be
20   stepwise increased until synchronization, or until the
remote frequency reaches $+f_2$, in which case the remote
frequency is changed back to the initial synchronization
frequency, $-f_2$, and the ranging process begins anew.

          While a stepwise increase of the remote frequency
25   from an initial frequency offset $-\Delta f_2$ has been described,
the initial synchronizing frequency can be set at a
predetermined frequency offset greater than $f_0$, for
example $+f_2$, and stepwise decreases of the remote

frequency can be·utilized to bring the remote radio to synchronization with the hub radio.

While preferred embodiments of the present invention have been described, it is to be understood that the

5    embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occurring to those skilled in the art from a perusal

10   hereof.

**WHAT IS CLAIMED:**

    1.   In a communication system having a hub radio and at least one remote radio, where the hub radio operates at a first frequency $f_0$ and includes a modem with a

5   tolerance range of synchronization of $\pm \Delta f_1$, a method of synchronizing the remote radio with the hub radio comprising the steps of:

    a.  transmitting a first ranging signal from the remote radio to the hub radio;

10    b.  receiving the ranging signal at the hub radio;

    c.  evaluating the ranging signal received at the hub and transmitting a synchronizing signal from the hub radio to the remote radio if the hub radio can not synchronize with the received ranging signal after a

15   predetermined period of time;

    d.  receiving the synchronizing signal from the hub radio at the remote radio and adjusting the frequency of transmission of the remote radio to a predetermined frequency outside the tolerance range of the modem from

20   $f_0$;

    e.  transmitting a ranging signal from the remote radio at the adjusted frequency to the hub radio;

    f.  evaluating the most recently received ranging signal at the hub radio and transmitting a synchronizing

25   signal from the hub radio to the remote radio if the hub radio can not synchronize with the ranging signal after a predetermined period of time;

g.   receiving    the    most    recently    received
synchronizing signal from the hub radio at the remote
radio and adjusting the frequency of transmission of the
remote radio by a predetermined frequency correction;

5        h.   transmitting a ranging signal from the remote
signal at the adjusted frequency; and

i.   repeating steps f)-h) until the hub radio can
synchronize with the received ranging signal.

2.   The method of Claim 1 wherein:

10       the    step    of    adjusting    the    frequency    of
transmission of the remote radio to a predetermined
frequency outside the tolerance range of the modem
includes lowering the transmission frequency of the
remote lower than $f_0$, and

15       the step of adjusting the frequency of the remote
radio by a predetermined frequency correction includes
stepwise increasing of the transmission frequency of the
remote.

3.   The method of Claim 1 wherein:

20       the    step    of    adjusting    the    frequency    of
transmission of the remote radio to a predetermined
frequency outside the tolerance range of the modem
includes raising the transmission frequency of the
remote higher than $f_0$, and

25       the step of adjusting the frequency of the remote
radio by a predetermined frequency correction includes
stepwise decreasing of the transmission frequency of the
remote.

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4. The method of Claim 1 where the predetermined frequency outside of the tolerance range of the modem is offset from $f_0$ by approximately 400kHz.

5. The method of Claim 1 where the predetermined frequency correction is a function of the tolerance of the modem.

6. The method of Claim 5 where the predetermined frequency correction is approximately equal to the tolerance of the modem.

7. The method of Claim 1 where the hub and remote radio transmit utilizing

Time Division Multiple Access (TDMA) point to multipoint communication.

8. A communication system having a hub radio and at least one remote radio, a method of synchronizing the hub radio and the remote radio to the same frequency, said hub radio capable of synchronizing within a predetermined frequency offset, comprising the steps of:

a. transmitting first modulated ranging data from a remote radio to the hub radio at a first frequency;

b. receiving the ranging data at the hub radio for demodulation;

c. transmitting a first synchronizing message from the hub radio to the remote radio if the hub radio is unable to demodulate the received ranging data after a predetermined period of time;

d. receiving the synchronizing message at the remote radio and adjusting the transmitting frequency of the

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remote radio to an initial synchronizing frequency in response thereto;

e. transmitting ranging data from the remote radio to the hub radio at the adjusted frequency; and

5    f. receiving the most recently received ranging data transmitted by the remote radio at the hub radio for demodulation;

g. transmitting a synchronizing message from the hub radio to the remote radio if the hub radio is unable to
10  demodulate the ranging data after a predetermined period of time;

h. receiving the most recently received synchronizing message at the remote radio and adjusting the transmitting frequency of the remote radio as a
15  function of the predetermined frequency offset;

i. transmitting ranging data from the remote radio to the hub radio at the adjusted frequency; and

j. repeating steps f-i until the hub radio successfully demodulates the ranging data.

20  9. The method of Claim 8 wherein:

the step of adjusting the frequency of transmission of the remote radio to an initial synchronizing frequency includes lowering the transmission frequency of the remote lower than $f_0$, and

25  the step of adjusting the frequency of the remote radio as a function of the predetermined frequency offset includes stepwise increasing the transmission frequency of the remote.

10. The method of Claim 8 wherein:

the step adjusting the frequency of transmission of the remote radio to an initial synchronizing frequency includes raising the transmission frequency of

5 the remote higher than $f_0$, and

the step of adjusting the frequency of the remote radio as a function of the predetermined frequency offset includes stepwise decreasing the transmission frequency of the remote.

10 11. The method of Claim 8 where the initial synchronizing frequency is offset from $f_0$ by approximately 400kHz.

12. The method of Claim 8 where the hub and remote radio transmit utilizing

15 using Time Division Multiple Access (TDMA) point to multipoint communication.
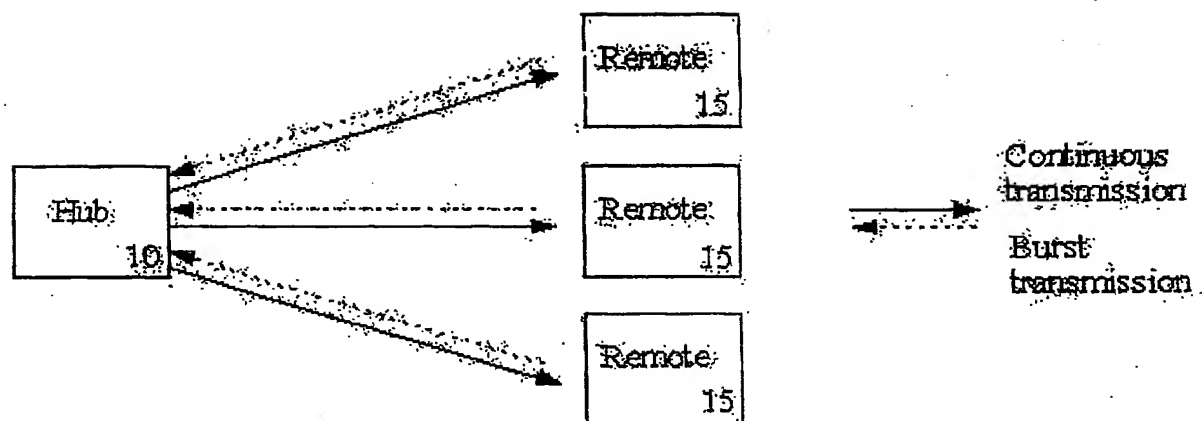
13. In a communication system using Time Division Multiple Access (TDMA) having a hub radio and at least one remote radio, where the hub radio is capable of

20 synchronizing with the remote radio within a predetermined frequency offset and where the hub radio synchronizes with the remote radio by providing frequency feedback to the remote radio, the improvement comprising wherein the hub radio causes the remote radio

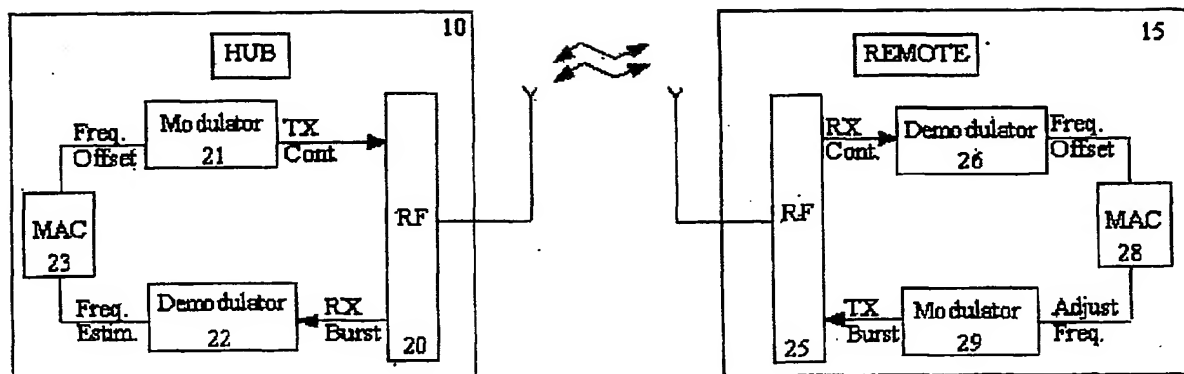25 to change transmitting frequency of the remote radio as a function of the predetermined frequency offset.

14. In a communication system using Time Division Multiple Access (TDMA) having a hub radio and at least

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one remote radio, where the hub radio is capable of synchronizing with the remote radio within a predetermined frequency offset and within a predetermined period of time, the improvement comprising

5   wherein the transmitting frequency of the remote radio is stepwise changed as a function of the predetermined frequency offset to thereby increase the frequency range of capture of hub radio within the predetermined period of time.

10   15. The method of Claim 14, wherein each stepped change in transmitting frequency of the remote is approximately equal to the predetermined frequency offset.

16. In a communication system using Time Division

15   Multiple Access (TDMA) having a hub radio and at least one remote radio, where the hub radio is capable of synchronizing with the remote radio within a predetermined frequency tolerance and where the hub radio synchronizes with the remote radio by providing

20   frequency feedback to the remote radio, the improvement comprising wherein the hub radio initially causes the remote radio to change transmitting frequency of the remote radio to a frequency outside of the predetermined frequency tolerance when the hub radio senses that the

25   remote radio is no longer synchronized.

**FIGURE 1**

FIGURE 2

FIGURE 3